

Title

2 Lighted Status Indicator Corresponding to the Positions of Circuit Breaker, Switch or
3 Fuse

5 This application claims priority on provisional application Serial No. 60/172,187, filed
6 December 17, 1999.

8 Technical Field

9 This invention relates, in general, to circuit breakers, switches, and fuses used in
10 electronic circuits, and in particular, to status indicators and momentary test switches for
11 circuit breakers.

13 Background Art

14 An evaluation of patents in this field (status indicators for circuit breakers, switches, or
15 fuses) reveals that existing technology is significantly different from, and inferior to, that
16 claimed by the applicant.

Relevant US patents examined were: 4,056,816 (Guim), 4,652,867 (Masot), 4,672,351 (Cheng), 5,233,330 (Hase), 5,343,192 (Yenisey), 5,353,014 (Carroll et al.), 5,812,352 (Rokita et al.), and 5,920,451 (Fasano et al.)

22 Evaluation of relevant patents in this field has revealed that:

- 24 o All previously issued patents describe a circuit that uses a single indicator to indicate
25 either the “OPEN/TRIPPED” or the “CLOSED” position, or uses multiple indicators
26 (usually separate LEDs) to display multiple possible conditions. Existing technology
27 does not allow a single lighted display element to indicate status for *all* possible
28 breaker, switch, or fuse conditions. *PP/11/11/11*

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- 1 ◦ Some of the issued patents require that a parallel circuit or set of contacts be
2 implemented together with the circuit breaker, switch, or fuse in order to activate the
3 indicator light.
4
- 5 ◦ Some patents in this area require active elements to monitor the status of the circuit
6 breaker or switch. Such circuits are less reliable and more expensive than circuits that
7 use only passive elements.
8
- 9 ◦ Some of the previously issued patents apply only to AC or DC powered systems.
10 Those used in DC systems may or may not function with both polarities.
11
- 12 ◦ None of the technologies in existing patents incorporates a momentary test switch
13 circuit that allows all circuit breaker, switch, or fuse status indicators to be
14 simultaneously tested, using a single bi-color lighted status indicator per
15 breaker/switch.
16
- 17 ◦ Finally, all circuits described in related patents are designed to be used with specific
18 supply voltages and will not function correctly outside that supply range.
19

20 The invention claimed by the applicants addresses all these problems. It describes a
21 circuit breaker, switch, or fuse status indicator that incorporates a lighted visual display
22 *with a multi-color light source*, eliminating the need for multiple light sources (such as
23 LEDs or back-lit LCDs) to display the various possible positions of a breaker.

24
25 A circuit that uses a single multi-color light source for status display is superior to
26 existing circuits with multiple light sources. Using of multiple light sources introduces
27 extra expense and complexity to status indicator circuitry and can unnecessarily consume
28 scarce room on the front of circuit breaker (or a panel adjacent to the circuit breaker).

29
30 The circuit breaker status indicator uses an inexpensive, passive electronic circuit that
31 takes advantage of the status contact switch of the circuit breaker to change the color of

that light source, depending upon the status (or position) of the circuit breaker. This circuit can also easily be configured to support a wide range of AC and DC (both positive and negative) voltages, and to include a momentary test switch circuit.

Summary

A lighted status indicator for a contact (circuit breaker, switch or fuse) with a distinctive color associated with each position of the circuit breaker. The lighted status indicator is composed of a multi-color light source (usually an LED) together with an electronic circuit that changes the color of that light source, depending upon the status (or position) of the circuit breaker, switch, or fuse. This lighted status indicator features a number of innovations, including:

- Use of simple, non-active, and inexpensive electronic parts,
- Use of a single, bi-color light LED to indicate the “ON” and “OFF” conditions of a two-position circuit breaker or switch with two distinct colors (example: red and green), and
- Use of a single bi-color LED to indicate status in a circuit breaker with a mid-position feature (on/off/tripped–3 positions in all). This allows these three possible status conditions (positions) to be represented by two different colors in the “ON” and the “TRIPPED” positions, and by the LED being off in the manually set “OFF” condition. (A three-color light source could also be used with this technology, allowing the “ON,” “TRIPPED,” and “OFF” states to all be represented by a unique color.)

This technology also offers heretofore-unseen flexibility of implementation. The lighted status indicator may be:

- Used with AC, or DC (positive or negative ground) power supplies,
- Used in a wide supply voltage range,
- Either external to the circuit breaker (or switch or fuse) or incorporated into the circuit breaker (or switch or fuse),

Brief Description of the Drawings

FIG. 1 is a circuit diagram of the Lighted Status Indicator circuit, where the switch is placed on the positive line, before line reaching the load, for a negative ground DC system.

FIG. 2 is the same as FIG. 1, except that the circuit now includes current-limiting diodes.

FIG. 3 is the same as FIG. 1, except that the circuit has been altered to work with an AC power supply.

FIG. 4 is the same as FIG. 1, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. 5 is a circuit diagram of the Lighted Status Indicator circuit, where the switch is placed on the negative line, before line reaching the load, for a positive ground DC system.

FIG. 6 is the same as FIG. 5, except that the circuit now includes current-limiting diodes.

FIG. 7 is the same as FIG. 5, except that the circuit has been altered to work with an AC power supply.

FIG. 8 is the same as FIG. 5, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. 9 is a circuit diagram of the Lighted Status Indicator circuit, where the circuit supports a lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, for a positive ground DC system.

FIG. 10 is the same as FIG. 9, except that the circuit now includes current-limiting diodes.

FIG. 11 is the same as FIG. 9, except that the circuit has been altered to work with an AC power supply.

FIG. 12 is the same as FIG. 9, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. 13 is a circuit diagram of the Lighted Status Indicator circuit, where the circuit supports a lighted position/status indicator for a mid-trip circuit breaker, with a built-in auxiliary switch. This circuit uses a bi-color LED, with the circuit breaker located between the positive side of power supply and load, and is designed for a negative ground DC system.

FIG. 14 is the same as FIG. 13, except that the circuit now incorporates current limiting diodes. This circuit is designed for a negative ground DC system.

FIG. 15 is the same as FIG. 13, except that the circuit has been altered to also work with an AC power supply.

FIG. 16 is the same as FIG. 13, except that the circuit incorporates both the current-limiting diodes and AC power supply support.

FIG. 17 is a circuit diagram of the Lighted Status Indicator circuit where the circuit supports a lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, for a positive ground DC system. This circuit represents a lower power dissipation option than that shown in FIG. 9.

FIG. **18** is the same as FIG. **17**, except that the circuit now includes a current-limiting diode.

FIG. **19** is the same as FIG. **17**, except that the circuit has been altered to also work with an AC power supply.

FIG. **20** is the same as FIG. **17**, except that the circuit incorporates both the current-limiting diode and AC power supply support.

FIG. **21** is a circuit diagram of the of the Lighted Status Indicator circuit where the circuit breaker is located between the positive side of power supply and load, for a negative ground DC system, that incorporates the lower power dissipation option.

FIG. **22** is the same as FIG. **21**, except that the circuit now includes a current-limiting diode.

FIG. **23** is the same as FIG. **21**, except that the circuit has been altered to also work with an AC power supply.

FIG. **24** is the same as FIG. **21**, except that this version of the circuit incorporates both the current-limiting diode and AC power supply support.

FIG. **25** is a circuit diagram of the Lighted Status Indicator circuit where the circuit supports the lighted position/status indicator as shown in FIG. **9**, and incorporates a circuit alarm test feature.

FIG. **26** is a circuit diagram of the Lighted Status Indicator circuit where the circuit supports an alarm test circuit for several lighted position/status indicator circuit breakers.



1 FIG. 27 is a circuit diagram for a one rack unit power distribution unit (PDU) using mid-
2 trip circuit breaker, with lighted status/position indicators and an alarm test circuit, for a
3 positive ground DC system.

4 FIG. 28 illustrates the one rack unit PDU, using mid-trip circuit breaker, lighted
5 status/position indicators, and an alarm test circuit, diagrammed in FIG. 27.

6

7 FIG. 29 shows a compact circuit breaker incorporating a mid-trip switch, a lighted status
8 indicator for the ON/OFF/TRIPPED positions, auxiliary “normally open”/“normally closed”
9 contact points for remote monitoring of the circuit breaker system, and an alarm circuit
10 momentary test switch, for AC or positive or negative ground DC systems.

11

12 FIG. 30 is a circuit diagram for the compact circuit breaker shown in FIG. 29, with a
13 lighted status indicator for ON/OFF/TRIPPED positions, for a positive ground DC system.

14

15 FIG. 31 shows how the circuit diagram in FIG. 30 could be modified to support a DPDT
16 (Dual Poll, Dual Throw) momentary test switch

17

18 FIG. 32 shows the FIG. 30 circuit with the addition of two current-limiting diodes.

19

20 FIG. 33 shows the FIG. 30 circuit reconfigured to support an AC power supply.

21

22 FIG. 34 shows the FIG. 30 circuit reconfigured to incorporate both current-limiting
23 diodes and AC power supply support.

24

25 FIG. 35 is a circuit diagram of the Lighted Status Indicator circuit for a mid-trip circuit
26 breaker, using a SPDT as a main contact and an auxiliary switch SPDT for tripped status
27 indication, for a positive ground DC system.

28

29 FIG. 36 is the same as FIG. 35, except that the circuit has been altered to work with a
30 negative ground DC system.

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1 . FIG. **45** illustrates side and front views of the L-Module—a compact breaker-mounted
2 module display of individual breaker status.

3

4 FIG. **46** illustrates a side view of a series of L-Modules daisy-chained together, and
5 monitored by an Alarm/Status Module.

6

7 FIG. **47** is a circuit diagram of the Alarm/Status Module, together with a series of daisy-
8 chained L-Modules that it monitors.

9

10 FIG. **48** is a circuit diagram of a variation of the Alarm/Status Module designed for use in
11 a dual power system.

12

13 FIG. **49** illustrates side and front views of the Direct Status Output L-Module—a compact
14 breaker-mounted module display of individual breaker status, designed to support
15 independent monitoring of individual circuit breakers.

16

17 FIG. **50** is a circuit diagram of the Direct Status Output L-Module.

18

19 FIG. **51** is a circuit diagram of an L-Module designed for a switch, fuse, or circuit breaker
20 with no auxiliary switch, or circuit breakers with no mid-trip capability.

21

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1 The values of resistors **4**, **2**, and **3** control the amount of the current flowing from point B
2 **9** to point A **8**, with a minimum value of 10 mA and a maximum value of 20 mA (typical
3 functional current range for an LED).

4
5 When the circuit breaker/switch/fuse **1** is OPEN/TRIPPED, current will flow from point C
6 **10** to point A **8**, and then divide into two parts. A portion of that current flows from point
7 A **8** to point B **9** (passing through the LED **5**), and then from point B **9** to point F **12**,
8 (passing though the resistor **4**). This current stream causes the bi-color LED **5** to glow
9 RED. A second portion of the current will flow from point A **8** to point F **12** (passing
10 through the resistor **3**). The diode **6** will block any current flow from point B **9** to point D
11 **11**. (In FIG. 1—as in the rest of this document—RED is used as an example of an
12 indicator color; other color LEDs or light sources could be substituted with no significant
13 changes to the circuits described.)

14
15 The values of resistors **4**, **2**, and **3** control the amount of the current flowing through the
16 LED **5** in the direction of point A **8** to point B **9**. In this case, the minimum current flow
17 will also be 10 mA and the maximum will be 20 mA, depending on the desired light
18 intensity and amount of power dissipation.

19
20
21 **Item 2: Switch placed on the positive line, before line reaching the load, with**
22 **current-limiting diodes, for a negative ground DC system.**

23
24 *Description:*

25 FIG. 2 is identical to the FIG. 1 circuit, except that two current-limiting diodes (**15** and
26 **18**) have been added in series with the resistors, **17** and **16**. These diodes act to limit the
27 current through the LED **19** to a maximum allowed by the diode specification (typically
28 10 to 15 mA).

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| | | | |
|---|-----------------------------------|-----------------------------------|----------------------|
| 2 | 13 –Switch | 18 –Current-limiting Diode | 23 –Point "B" |
| 3 | 14 –Resistor | 19 –Bi-Color LED | 24 –Point "C" |
| 4 | 15 –Current-limiting Diode | 20 –Diode | 25 –Point "D" |
| 5 | 16 –Resistor | 21 –Load | 26 –Point "F" |
| 6 | 17 –Resistor | 22 –Point "A" | |

9 Adding these current-limiting diodes allows the circuit to be used with a wide range of
10 supply voltages. Current through the LED **19** will not exceed the regulating current of the
11 diodes **15** or **18**. Diode **15** regulates the LED current in the direction of point B **23** to
12 point A **22** (LED is GREEN; breaker/switch/fuse is CLOSED), while diode **18** regulates the
13 LED current in the direction of point A **22** to point B **23** (LED is RED;
14 breaker/switch/fuse is OPEN/TRIPPED).

The maximum DC supply voltage tolerated by the circuit will depend on the maximum voltage allowed across the diode **15** or **18** (typically 50 VDC). It will be equal to the maximum voltage allowed across diode **15** (or **18**) plus the voltage across the resistor **16** (or **17**). Since the current through these resistors (**16** or **17**) is limited by the diodes **15** and **18**, the voltages will also be limited

The circuit in FIG. 2 can be easily modified for use at a higher DC supply voltages. To support increased voltages, it is necessary to add one or more additional current-limiting diodes in series with diode 15 and 18. Typically, each extra current-limiting diode added, in series, with the resistors 17 and 16 will increase the DC supply voltage limit by 50 VDC. This circuit will also function with just the two current-limiting diodes, and without the resistors, 17 and 16.



1 **Item 3: Switch placed on the line, before line reaching the load, for use with AC**
2 **power supply.**

3

4 *Description:*

5 Using the circuit shown in FIG. 1 as a base, a diode **28** (similar to the diode **33**) is added
6 on the path of junction point C **37** to resistor **29**, resulting in the circuit in FIG. 3.

7

8 *Elements of the FIG. 3 Circuit:*

| | | |
|------------------------|-------------------------|----------------------|
| 9 27 –Switch | 32 –Bi-Color LED | 37 –Point "C" |
| 10 28 –Diode | 33 –Diode | 38 –Point "D" |
| 11 29 –Resistor | 34 –Load | 39 –Point "F" |
| 12 30 –Resistor | 35 –Point "A" | |
| 13 31 –Resistor | 36 –Point "B" | |

14

15 *Function:*

16 Adding the extra diode **28** allows the circuit to be used with an AC power supply, as well
17 as with a negative ground DC power supply. The functionality of the circuit remains the
18 same, except that the current will now flow in half cycles in either direction through the
19 LED **32**, depending on the position of the on/off switch.

20

21

22 **Item 4: Switch placed on the line, before line reaching the load, with current-**
23 **limiting diodes, for use with AC power supply.**

24

25 *Description:*

26 Adding current-limiting diodes, **43** and **46**, to the circuit in FIG. 3 allows a wider AC
27 supply voltage range to be tolerated. FIG. 4 shows such a configuration.

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1 *Elements of the FIG. 4 Circuit:*

| | | | |
|---|-----------------------------------|-----------------------------------|----------------------|
| 2 | 40 –Switch | 45 –Resistor | 50 –Point "A" |
| 3 | 41 –Diode | 46 –Current-Limiting Diode | 51 –Point "B" |
| 4 | 42 –Resistor | 47 –Bi-Color LED | 52 –Point "C" |
| 5 | 43 –Current-Limiting Diode | 48 –Diode | 53 –Point "D" |
| 6 | 44 –Resistor | 49 –Load | 54 –Point "F" |

7

8 *Function:*

9 The addition of the current-limiting diodes, in series, with the diodes **43** and **46** increases
10 the circuit's AC supply voltage limit, while not allowing the current through the LED **47**
11 to exceed that LED's limits. The maximum voltage tolerated corresponds to the peak
12 voltage of the positive half cycle of the AC power supply. This circuit could also be used
13 with just the two current limiting diodes, **43** and **46**, and without the two resistors, **44**
14 and **45**.

15

16

17 **Item 5: Switch placed on the negative line, before line reaching the load, positive**
18 **ground DC system.**

19

20 *Description:*

21 The circuit in FIG. **5** consists of three resistors (**57**, **59**, and **58**), a diode (**61**), and a bi-
22 color LED **60**. The circuit is connected across the circuit breaker/switch/fuse **55**, with
23 resistor **59** connected to point F **66**, and diode **61** connected between points B **63** and D
24 **65**. The common connection point of resistors **57** and **58** is connected to the positive side
25 of the DC supply at point C **64**.

26

27 *Elements of the FIG. 5 Circuit:*

| | | | |
|----|---------------------|-------------------------|----------------------|
| 28 | 55 –Switch | 59 –Resistor | 63 –Point "B" |
| 29 | 56 –Load | 60 –Bi-Color LED | 64 –Point "C" |
| 30 | 57 –Resistor | 61 –Diode | 65 –Point "D" |
| 31 | 58 –Resistor | 62 –Point "A" | 66 –Point "F" |



1 *Function:*

2 When the circuit breaker/switch/fuse **55** is CLOSED, a current will flow through the
3 resistor **58**, the LED **60**, the diode **61**, and through the switch **55** to point F **66**. This
4 current stream causes the LED **60** to glow GREEN.

5

6 A second path of current will run from point C **64** to point F **66** (passing through the
7 resistor **57**, the diode **61**, and the switch **55**). A small amount of current will also run from
8 point A **62** to point F **66** (passing through resistor **59**). This current is equal to the voltage
9 drop across the LED **60** and the diode **61** (equal to 2 diode drops), divided by the value of
10 the resistor **59**.

11

12 The values of resistors **57**, **59**, and **58** will control the amount of the current flowing from
13 point A **62** to point B **63**, with a minimum value of 10 mA and a maximum value of 20
14 mA (typical functional current range for an LED).

15

16 When the circuit breaker/switch/fuse is OPEN/TRIPPED, current will flow from point C **64**
17 to point B **63**, and then from point B **63** to point A **62** (passing though the LED **60**), and
18 then from point A **62** to point F **66**. This current will cause the bi-color LED **60** to glow
19 RED. A second path of current will flow from point C **64** to point A **62** (passing though
20 the resistor **58**, and then through the resistor **59**) to point F **66**.

21

22 The values of resistors **57**, **59**, and **58** will control the amount of the current flowing
23 through the LED **60** in the direction of point B **63** to point A **62**. The minimum current
24 will be 10 mA and the maximum will be 20 mA, depending on the desired light intensity
25 and amount of power dissipation.

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1 **Item 6: Switch placed on the negative line, before line reaching the load, with**
2 **current-limiting diodes, for a positive ground DC system.**

3

4 *Description:*

5 The circuit in FIG. 6 is identical to that shown in FIG. 5, except that two current-limiting
6 diodes, **71** and **69**, have been added in series with the resistors, **70** and **72**.

7

8 *Elements of the FIG. 6 Circuit:*

| | | |
|--------------------------------------|-------------------------|----------------------|
| 9 67 –Switch | 72 –Resistor | 77 –Point "B" |
| 10 68 –Load | 73 –Resistor | 78 –Point "C" |
| 11 69 –Current-Limiting Diode | 74 –Bi-Color LED | 79 –Point "D" |
| 12 70 –Resistor | 75 –Diode | 80 –Point "F" |
| 13 71 –Current-Limiting Diode | 76 –Point "A" | |

14

15 *Function:*

16 As previously explained under Item 2, the addition of current-limiting diodes (**69** and **71**)
17 regulates the maximum current flow, and increases the range of DC supply voltages that
18 the circuit will tolerate.

19

20 The circuit in FIG. 6 could be easily modified to support higher DC supply voltages.

21 Placing additional current-limiting diodes, in series with the diodes **71** and **69**, will
22 further increase the DC supply voltage limit. This circuit could also be used with just the
23 two current-limiting diodes, and without the two resistors, **70** and **72**.

24

25

26 **Item 7: Switch placed on the line, before line reaching the load, for use with AC**
27 **power supply.**

28

29 *Description:*

30 FIG. 7 shows the addition a diode **88** (similar to the diode **87**) on the path of junction
31 point F **93** to the resistor **85**, to the circuit diagrammed in FIG. 5



1 *Elements of the FIG. 7 Circuit:*

| | | | |
|---|---------------------|-------------------------|----------------------|
| 2 | 81 –Switch | 86 –Bi-Color LED | 91 –Point "C" |
| 3 | 82 –Load | 87 –Diode | 92 –Point "D" |
| 4 | 83 –Resistor | 88 –Diode | 93 –Point "F" |
| 5 | 84 –Resistor | 89 –Point "A" | |
| 6 | 85 –Resistor | 90 –Point "B" | |

7

8 *Function:*

By adding this additional diode **88**, the FIG. 7 circuit can be used with either an AC power supply or positive ground DC power supply (as described under Item 3).

11

12

13 **Item 8: Switch placed on the line, before line reaching the load, with current-**
14 **limiting diodes, for use with AC power supply**

15

16 *Description:*

Adding current-limiting diodes, **98** and **96**, to the circuit shown in FIG. 7 allows a wider AC supply voltage range to be tolerated. FIG. 8 shows such a configuration.

19

20 *Elements of the FIG. 8 Circuit:*

| | | | |
|----|-----------------------------------|--------------------------|-----------------------|
| 21 | 94 –Switch | 99 –Resistor | 104 –Point "A" |
| 22 | 95 –Load | 100 –Resistor | 105 –Point "B" |
| 23 | 96 –Current-Limiting Diode | 101 –Bi-Color LED | 106 –Point "C" |
| 24 | 97 –Resistor | 102 –Diode | 107 –Point "D" |
| 25 | 98 –Current-Limiting Diode | 103 –Diode | 108 –Point "F" |

26

27 *Function:*

28 The addition of more current-limiting diodes, in series, with the diodes, **98** and **96**,
29 increases the AC supply voltage limit (as explained under Item 4). This circuit could also
30 be used with just the two current-limiting diodes, **98** and **96**, and without the resistors, **97**
31 and **99**.



Item 9: Lighted position/status indicator for a mid-trip circuit breaker with built-in auxiliary switch, using a bi-color LED, positive ground system.

Description:

A mid-trip circuit breaker is a switch that automatically opens up when the current passing through the switch contacts exceeds a pre-set value. Included in the circuit breaker structure is a separate auxiliary switch—a STDT (single pole, double throw) switch. This auxiliary switch only changes status when the circuit breaker is in a TRIPPED state. Manually opening or closing the circuit breaker does not change the status of the auxiliary switch. Depending upon the application, this auxiliary switch is either used to remotely monitor the status of the circuit breaker, or to remotely activate other devices.

The circuit in FIG. 9 contains two resistors (**112** and **115**), a diode (**111**), and a bi-color LED **113** that indicates the status of the circuit breaker. This LED **113** either glows GREEN or RED, or is OFF, depending upon the status of the circuit breaker.

The diode **111** and the resistor **115** are connected, respectively, to points D **116** and F **118** of the circuit breaker. Point F **118** is also connected to the negative point of the DC power supply, while point D **116** is connected to the negative input of the load **110**. One side of the LED **113** is connected to resistor **112** and to the “normally open” side of the auxiliary switch **114**. The other side of the LED **113** is connected to the resistor **115** and to the “normally closed” side of the auxiliary switch **114**. The center position of the auxiliary switch **114** is connected to the positive side of the power supply.

Elements of the FIG. 9 Circuit:

| | | |
|-----------------------------|------------------------------|-----------------------|
| 109 –Circuit Breaker | 113 –Bi-Color LED | 117 –Point "E" |
| 110 –Load | 114 –Auxiliary Switch | 118 –Point "F" |
| 111 –Diode | 115 –Resistor | |
| 112 –Resistor | 116 –Point "D" | |

Function:

Under normal conditions (when the circuit breaker is in the CLOSED state), a current flows from point E **117** (+VDC), through the “normally closed” contact of the auxiliary switch **114**, the LED **113**, the resistor **112**, the diode **111**, the circuit breaker **109**, point F **118**, and on to the negative of the power supply). This current will cause the bi-color LED **113** to glow GREEN. A second path of current will also run through the auxiliary switch **114** to point F **118** (passing through the resistor **115**).

When the circuit breaker **109** is manually turned to the OFF position, no current will flow through the LED **113**, and the LED **113** will be in OFF state. In this condition, current will still flow through the auxiliary switch **114** to point F **118** (passing through resistor **115**), and on to the negative side of the power supply. (In FIG. 9—as in the rest of this document—the OFF state is used as an example of an indicator “color.” A three-state LED, using any three colors—or any two colors and an OFF state—could be substituted with no significant changes to the circuits described.)

When the circuit breaker **109** is TRIPPED (in an over limit current condition), it will automatically open the circuit breaker main contact, and also activate the auxiliary switch **114**. When that happens, a current will flow from point E **117** (+VDC circuit ground) through the auxiliary switch **114** (from the “center” to “normally open” points) to point F **118** (passing through the LED **113**, and the resistor **115**). This current flow will cause the LED to turn RED, indicating an alarm condition.

The values selected for the resistors **112** and **115** depend on the desired light intensity for the LED **113** (for both GREEN and RED states), and power dissipation considerations.

Item 10: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, with current-limiting diodes, for a positive ground DC system.



1 *Description:*

2 FIG. 10 is identical to the FIG. 9 circuit, except that two current-limiting diodes (123 and
3 126) have been added in series with the resistors (122 and 127). These diodes restrict the
4 current through the LED 124 to a maximum allowed by the diode specifications.

5
6 *Elements of the FIG. 10 Circuit:*

| | | |
|------------------------------|---------------|----------------------------|
| 7 125–Auxiliary Switch | 129–Point "E" | 121–Diode |
| 8 126–Current-Limiting Diode | 130–Point "F" | 122–Resistor |
| 9 127–Resistor | 119–Breaker | 123–Current-Limiting Diode |
| 10 128–Point "D" | 120–Load | 124–Bi-Color LED |

11
12 *Function:*

13 Adding the current-limiting diodes will allow the circuit to be used with a wider DC
14 supply voltage range. In this configuration, the current through the LED 124 can not
15 exceed the regulating current of the diodes, 123 and 126.

16
17 The circuit could also be used with just the two current-limiting diodes, 123 and 126, and
18 without the two resistors, 122 and 127. Adding additional current-limiting diodes, in
19 series, will further increase the DC supply voltage tolerated.

20
21
22 **Item 11: Lighted position/status indicator for a mid-trip circuit breaker, with built-**
23 **in auxiliary switch, using bi-color LED, for use with AC power supply.**

24
25 *Description:*

26 In FIG. 11, the circuit shown in FIG. 9 is modified by the addition of a diode 138 (similar
27 to the diode CR 133) on the path of junction point F 141 to resistor 137.

03012345678910111213141516171819202122232425262728293031

Elements of the FIG. 11 Circuit:

| | | |
|-----------------------------|------------------------------|-----------------------|
| 131 –Circuit Breaker | 135 –Bi-Color LED | 139 –Point "D" |
| 132 –Load | 136 –Auxiliary Switch | 140 –Point "E" |
| 133 –Diode | 137 –Resistor | 141 –Point "F" |
| 134 –Resistor | 138 –Diode | |

Function:

Adding the diode **138** allows the circuit to be used with AC power supplies, as well as with DC power supplies (for positive ground systems). The functionality of the circuit remains the same, except that the current will now flow in half cycles in either direction through the LED **135**.

Item 12: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, with current-limiting diodes, for use with AC power supply.

Description:

By adding current-limiting diodes, **146** and **149**, to the circuit shown in FIG. **11**, a wider AC supply voltage range can be tolerated. FIG. **12** shows this configuration.

Elements of the FIG. 12 Circuit:

| | | |
|------------------------------------|------------------------------------|-----------------------|
| 142 –Circuit Breaker | 147 –Bi-Color LED | 152 –Point "D" |
| 143 –Load | 148 –Auxiliary Switch | 153 –Point "E" |
| 144 –Diode | 149 –Current-Limiting Diode | 154 –Point "F" |
| 145 –Resistor | 150 –Resistor | |
| 146 –Current-Limiting Diode | 151 –Diode | |

Function:

The addition of more current-limiting diodes, in series, with the diodes, **146** and **149**, increases the AC supply voltage limit (as explained under Item 4).

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1 This circuit could also be used with just the two current-limiting diodes, **146** and **149**, and
2 without the resistors, **145** and **150**.

3

4

5 **Item 13: Lighted position/status indicator for a mid-trip circuit breaker (located**
6 **between the +VDC and the load) with built-in auxiliary switch, using a bi-color**
7 **LED, negative ground system.**

8

9 *Description:*

10 FIG. **13** illustrates how the status indicator circuit in FIG. **9** can be modified for use in a
11 negative ground DC system.

12

13 *Elements of the FIG. 13 Circuit:*

| | | |
|---------------------------------|-----------------------|-----------------------|
| 14 155 –Circuit Breaker | 159 –Resistor | 163 –Point "E" |
| 15 156 –Resistor | 160 –Diode | 164 –Point "F" |
| 16 157 –Auxiliary Switch | 161 –Load | |
| 17 158 –Bi-Color LED | 162 –Point "D" | |

18

19 *Function:*

20 The circuit in FIG. **13** functions identically to the circuit in FIG. **9**, except that the current
21 now flows from points D **162** and F **164** to point E **163** (passing through the components
22 on each of the paths).

23

24

25 **Item 14: Lighted position/status indicator for a mid-trip circuit breaker, with built-**
26 **in auxiliary switch, using bi-color LED, circuit breaker located between the positive**
27 **side of power supply and load, with current limiting diodes, for a negative ground**
28 **DC system.**

29

30

31

1 *Description:*

2 The circuit in FIG. 14 adds two current-limiting diodes, 170 and 167, in series with the
3 resistors, 171 and 166, to the circuit diagrammed in FIG. 13.

4

5 *Elements of the FIG. 14 Circuit:*

| | | | |
|---|----------------------------|----------------------------|---------------|
| 6 | 165–Circuit Breaker | 169–Bi-Color LED | 173–Load |
| 7 | 166–Resistor | 170–Current-Limiting Diode | 174–Point "D" |
| 8 | 167–Current-Limiting Diode | 171–Resistor | 175–Point "E" |
| 9 | 168–Auxiliary Switch | 172–Diode | 176–Point "F" |

10

11 *Function:*

12 The circuit in FIG. 14 functions identically to the circuit in FIG. 10, except that the
13 current now flows from points D 174 and F 176 to point E 175 (passing through the
14 components on each of the paths).

15

16

17 **Item 15: Lighted position/status indicator for a mid-trip circuit breaker, with built-**
18 **in auxiliary switch, using bi-color LED, circuit breaker located between line and the**
19 **load, for use with an AC power supply.**

20

21 *Description:*

22 FIG. 15 adds a diode, 178 (similar to the diode 183), between junction point F 187 and
23 resistor 179, to the circuit diagrammed in FIG. 13.

24

25 *Elements of the FIG. 15 Circuit:*

| | | | |
|----|----------------------|------------------|---------------|
| 26 | 177–Circuit Breaker | 181–Bi-Color LED | 185–Point "D" |
| 27 | 178–Diode | 182–Resistor | 186–Point "E" |
| 28 | 179–Resistor | 183–Diode | 187–Point "F" |
| 29 | 180–Auxiliary Switch | 184–Load | |

30

31

1 *Function:*

The addition of this diode **178** allows the circuit to be used with AC power supplies, as well as with DC power supplies (negative ground systems). The functionality of the circuit remains the same, except that the current will now flow in half cycles in either direction through the LED **181**.

6

7

8 **Item 16: Lighted position/status indicator for a mid-trip circuit breaker, with built-**
9 **in auxiliary switch, using bi-color LED, circuit breaker located between line and the**
10 **load, for use with an AC power supply, with current-limiting diodes.**

11

12 *Description:*

By adding the current-limiting diodes, **194** and **191**, to the circuit shown on FIG. **15**, a wider AC supply voltage range will be obtained. FIG. **16** shows this configuration.

15

16 *Elements of the FIG. 16 Circuit:*

17 **188**–Circuit Breaker **193**–Bi-Color LED **198**–Point "D"

18 **189–Diode** **194–Current-Limiting Diode** **199–Point "E"**

19 190–Resistor **195–Resistor** **200–Point "F"**

20 **191**–Current-Limiting Diode **196**–Diode

21 **192**-Auxiliary Switch **197**-Load

22

23 *Function:*

24 The addition of more current-limiting diodes, in series, with the diodes, **194** and **191**, will
25 increase the AC supply voltage limit (as explained under Item 4).

26

27 This circuit would also function with just the two current-limiting diodes, **194** and **191**,
28 and without the resistors, **195** and **190**.

29

30

Item 17: Lighted position/status indicator for a mid-trip circuit breaker (located between the +VDC and the load) with built-in auxiliary switch, using a bi-color LED, for a positive ground system, lower power dissipation option.

Description:

The circuit in FIG. 17 contains three resistors (207, 208, and 205), a diode (203), and a bi-color LED 204 that indicates the status of the circuit breaker. The FIG. 17 circuit modifies the FIG. 9 circuit by moving the resistor 207 to a point between resistor 208 and the “normally closed” contact of the auxiliary switch 206, and adding a third resistor 205 between the auxiliary switch 206 and point E 210 (+VDC supply). When using the FIG. 17 circuit in different applications, one side of the resistor 205 should always remain connected to the +VDC supply.

Elements of the FIG. 17 Circuit:

| | | |
|-----------------------------|------------------------------|-----------------------|
| 201 –Circuit Breaker | 205 –Resistor | 209 –Point "D" |
| 202 –Load | 206 –Auxiliary Switch | 210 –Point "E" |
| 203 –Diode | 207 –Resistor | 211 –Point "F" |
| 204 –Bi-Color LED | 208 –Resistor | |

Function:

This circuit dissipates less power than the circuit in FIG. 9, for the same LED current. Lower power dissipation is implemented via the addition of the third resistor **205**. When the auxiliary switch **206** is in the “normally closed” position, the current flow is from point E **210** through the resistors **205** and **207**, through the LED **204**, the diode **203**, the circuit breaker **201**, and into the negative side of the power supply. Because the voltage drop across the LED **204** and the diode **203** is very low in comparison to the VDC, the current that flows through the resistor **208** to the negative side of the supply is minimal.

When the auxiliary switch **206** is in the “normally open” position, the current flow will be from point E **210**, through the resistor **205**, the LED **204**, and the resistor **208**, and into the negative side of the power supply.



If resistor values are chosen so that resistor **207** = resistor **208**, for an optimum current value, the current levels through the LED **204** at both conditions (“RED” and “GREEN”) will be very close to each other. Current flow is less when the breaker is manually set to the OFF position (resistors **207**, **208**, and **205** are in series).

Item 18: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, lower power dissipation option, with a current-limiting diode, for a positive ground DC system.

Description:

The circuit in FIG. **18** adds a current-limiting diode **217**, in series, between the resistor **216** and point E **222**, to the circuit diagrammed in FIG. **17**.

Elements of the FIG. 18 Circuit:

| | | |
|-----------------------------|------------------------------------|-----------------------|
| 212 –Circuit Breaker | 216 –Resistor | 220 –Resistor |
| 213 –Load | 217 –Current-Limiting Diode | 221 –Point "D" |
| 214 –Diode | 218 –Auxiliary Switch | 222 –Point "E" |
| 215 –Bi-Color LED | 219 –Resistor | 223 –Point "F" |

Function:

Adding the diode **217** increases the DC power supply voltage tolerated, while keeping the current through the LED **215** within the desired limits.

The FIG. **18** circuit could also be modified to function without the resistor **216**, and with the resistor **219** replaced with a jumper wire (a zero ohm resistor).

Item 19: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, lower power dissipation option, for use with AC power supplies.

1 *Description:*

2 FIG. **19** modifies the circuit shown in FIG. **17**, adding an additional diode **232** (similar to
3 the diode CR **226**) between point F **235** and the resistor **231**.

4

5 *Elements of the FIG. 19 Circuit:*

| | | |
|-------------------------------|------------------------------|-----------------------|
| 6 224 –Circuit Breaker | 228 –Resistor | 232 –Diode |
| 7 225 –Load | 229 –Auxiliary Switch | 233 –Point "D" |
| 8 226 –Diode | 230 –Resistor | 234 –Point "E" |
| 9 227 –Bi-Color LED | 231 –Resistor | 235 –Point "F" |

10

11 *Function:*

12 Adding the extra diode **232** allows the circuit to be used with both AC and positive
13 ground DC power supplies.

14

15

16 **Item 20: Lighted position/status indicator for a mid-trip circuit breaker, with built-**
17 **in auxiliary switch, using bi-color LED, with current-limiting diode, incorporating**
18 **the lower power dissipation option, for use with AC power supplies.**

19

20 *Description:*

21 The circuit shown in FIG. **20** is identical to that in FIG. **19**, except that a current-limiting
22 diode **241** has been added between the resistor **240** and point E **247** (VAC Return).

23

24 *Elements of the FIG. 20 Circuit:*

| | | |
|--------------------------------|------------------------------------|-----------------------|
| 25 236 –Circuit Breaker | 241 –Current-Limiting Diode | 246 –Point "D" |
| 26 237 –Load | 242 –Auxiliary Switch | 247 –Point "E" |
| 27 238 –Diode | 243 –Resistor | 248 –Point "F" |
| 28 239 –Bi-Color LED | 244 –Resistor | |
| 29 240 –Resistor | 245 –Diode | |

30

31



1 *Function:*

2 The addition of the current-limiting diode **241** allows a wider AC (or positive DC
3 ground) supply voltage range to be tolerated.

4

5

6 **Item 21: Lighted position/status indicator for a mid-trip circuit breaker with built-**
7 **in auxiliary switch, using bi-color LED, with the circuit breaker located between the**
8 **positive side of power supply and load, for a negative ground DC system, lower**
9 **power dissipation option.**

10

11 *Description:*

12 The circuit in FIG. **21** shows how the FIG. **17** circuit can be altered to accommodate a
13 negative ground DC system. In the FIG. **21** circuit, the circuit breaker **249** is located
14 between the positive side of power supply and load **256**. This version of the lighted status
15 indicator circuit still supports a mid-trip circuit breaker with a built-in auxiliary switch
16 **253**, and incorporates the lower power dissipation option.

17

18 *Elements of the FIG. 21 Circuit:*

| | | |
|--------------------------------|------------------------------|-----------------------|
| 19 249 –Circuit Breaker | 253 –Auxiliary Switch | 257 –Point "D" |
| 20 250 –Resistor | 254 –Bi-Color LED | 258 –Point "E" |
| 21 251 –Resistor | 255 –Diode | 259 –Point "F" |
| 22 252 –Resistor | 256 –Load | |

23

24 *Function:*

25 Except for the changes required to support a negative ground DC system, the circuit in
26 FIG. **21** functions identically to the FIG. **17** circuit, dissipating less power than the
27 standard lighted status indicator circuit (negative ground) for a mid-trip breaker (shown
28 in FIG. **13**).

29

30

31

Item 22: Lighted position/status indicator for a mid-trip circuit breaker with built-in auxiliary switch, using bi-color LED, with the circuit breaker located between the positive side of power supply and load, for a negative ground DC system, with current-limiting diode, lower power dissipation option.

Description:

FIG. 22 adds a current-limiting diode 264, in series, between the resistor 263 and point E 270, to the circuit diagrammed in FIG. 21.

Elements of the FIG. 22 Circuit:

| | | |
|-----------------------------|------------------------------------|-----------------------|
| 260 –Circuit Breaker | 264 –Current-Limiting Diode | 268 –Load |
| 261 –Resistor | 265 –Auxiliary Switch | 269 –Point "D" |
| 262 –Resistor | 266 –Bi-Color LED | 270 –Point "E" |
| 263 –Resistor | 267 –Diode | 271 –Point "F" |

Function:

Adding the diode 264 increases the DC power supply voltage tolerated, while keeping the current through the LED 266 within the desired limits.

The FIG. 22 circuit could also be modified to function without the resistor 263, and with the resistor 262 replaced with a jumper wire (a zero ohm resistor).

Item 23: Lighted position/status indicator for a mid-trip circuit breaker, with built-in auxiliary switch, using bi-color LED, with the circuit breaker located between the positive side of power supply and load, for an AC (or negative ground DC) system, lower power dissipation option.

Description:

FIG. 23 modifies the circuit shown in FIG. 21, adding an additional diode 273 (similar to the diode CR 279) between point F 283 and the resistor 274.



| | | | |
|---|-----------------------------|------------------------------|-----------------------|
| 2 | 272 –Circuit Breaker | 276 –Resistor | 280 –Load |
| 3 | 273 –Diode | 277 –Auxiliary Switch | 281 –Point "D" |
| 4 | 274 –Resistor | 278 –Bi-Color LED | 282 –Point "E" |
| 5 | 275 –Resistor | 279 –Diode | 283 –Point "F" |

8 Adding the extra diode **273** allows the circuit to be used with both AC and negative
9 ground DC power supplies.

12 **Item 24. Lighted position/status indicator for a mid-trip circuit breaker with built-in**
13 **auxiliary switch, using bi-color LED, with the circuit breaker located between the**
14 **positive side of power supply and load, for an AC (or negative ground DC) system,**
15 **with current-limiting diode, lower power dissipation option.**

The circuit shown in FIG. **24** is identical to that in FIG. **23**, except that a current-limiting diode **289** has been added between the resistor **288** and point E **295** (VAC Return).

| | | | |
|----|-----------------------------|------------------------------------|-----------------------|
| 22 | 284 –Circuit Breaker | 289 –Current-Limiting Diode | 294 –Point "D" |
| 23 | 285 –Diode | 290 –Auxiliary Switch | 295 –Point "E" |
| 24 | 286 –Resistor | 291 –Bi-Color LED | 296 –Point "F" |
| 25 | 287 –Resistor | 292 –Diode | |
| 26 | 288 –Resistor | 293 –Load | |

29 The addition of the current-limiting diode **289** allows a wider AC (or negative DC
30 ground) supply voltage range to be tolerated.

Item 25: Lighted position/status indicator, with circuit alarm test feature (simulation of tripped auxiliary switch, circuit breakers automatically tripped), for a positive ground DC system.

Description:

The bulk of the circuit shown in FIG. 25 is identical to the FIG. 9 circuit—with one important exception. A test function has been added to the FIG. 9 circuit that allows the user to test the lighted status indicator circuit with on push-button test switch.

This test function is implemented by the addition of a momentary test switch 303 to the circuit. The momentary test switch's 303 "normally open" contact is connected to the "normally open" contact of the auxiliary switch 302, and its "normally closed" contact is connected to the center position of the auxiliary switch (point E) 306. Finally, the center position of the momentary test switch 303 is connected to point G 308 (+VDC).

Elements of the FIG. 25 Circuit:

| | | |
|-----------------------------|-----------------------------------|-----------------------|
| 297 –Circuit Breaker | 301 –Bi-Color LED | 305 –Point "D" |
| 298 –Load | 302 –Auxiliary Switch | 306 –Point "E" |
| 299 –Diode | 303 –Momentary Test Switch | 307 –Point "F" |
| 300 –Resistor | 304 –Resistor | 308 –Point "G" |

Function:

Under normal conditions (when the circuit breaker is in the CLOSED state), most of the current flows from point G 308 (+VDC), through the "normally closed" contact of the momentary test switch 303, through the auxiliary switch 302, the LED 301, the resistor 300, the diode 299, the circuit breaker 297, and then to point F 307 (negative of the DC supply). Part of the current branches off at the auxiliary switch 302 and flows to point F 307 (passing through the resistor 304).

When the momentary test switch 303 is depressed, the current flowing from point G 308 changes direction. It will flow from point G 308 to the "normally open" contact of the



1 In a TRIPPED condition, whether the momentary test switch **303** is pressed or not, the flow
2 of current will run the same direction through the LED **301**, and it will continue to glow
3 RED. Therefore the momentary test switch **303** could be activated anytime—regardless of
4 the circuit breaker **297** condition—without disturbing the load **298** functionality.

5
6 While the FIG. **25** circuit has been configured to support a positive ground DC system, a
7 similar approach could easily be used for a negative ground DC system. This circuit
8 would require only minor modifications (including reversal of the direction of the diode
9 **299** and bi-color LED **301**) to support a circuit breaker located between the positive side
10 of power supply and load **298** (as in the FIG. **13** circuit). The circuit in FIG. **25** may also
11 be built using the lower power dissipation designs previously described.

12
13
14 **Item 26: Alarm test circuit for several lighted position/status indicator circuit**
15 **breakers with auxiliary switch, for a positive ground DC system.**

16
17 *Description:*

18 FIG. **26** modifies FIG. **25**, adding a diode **314** between the “normally open” positions of
19 the auxiliary switch **317** and the momentary test switch **316**. The “normally open”
20 position of the momentary test switch **316** (point M **319**) is also connected to several
21 circuits similar to that shown in FIG. **25** (with an added diode), through several diodes
22 (D1, D2, ... and Dn **315**).

23
24 *Elements of the FIG. 26 Circuit:*

| | | |
|--------------------------------|-----------------------------------|------------------------------|
| 25 309 –Circuit Breaker | 313 –Bi-Color LED | 317 –Auxiliary Switch |
| 26 310 –Load | 314 –Diode | 318 –Resistor |
| 27 311 –Diode | 315 –Diodes D1 through Dn | 319 –Point "M" |
| 28 312 –Resistor | 316 –Momentary Test Switch | |

1 *Function:*

2 Pressing the momentary test switch **316** causes current to flow in the same direction
3 through all of the diodes (Diodes D1 through Dn) **315**, all of the connected circuits, and
4 through all of the LEDs associated with those circuits.

5
6 If all of these circuits are working properly, all the associated LEDs will turn RED.
7 Therefore, testing of several circuit breaker circuits can be accomplished using a single
8 momentary test switch. The diode **314** and the diodes D1 though Dn **315** serve to isolate
9 each circuit, so that if one circuit breaker is tripped and its auxiliary switch is activated,
10 no current will flow to the other circuits.

11
12 While the FIG. **26** circuit(s) have been configured to support a positive ground DC
13 system, a similar approach could easily be used for a negative ground DC system. This
14 circuit would require only minor modifications (including reversal of the direction of the
15 diode **311** and bi-color LED **313**) to support a circuit breaker located between the positive
16 side of power supply and load (as in the FIG. **13** circuit). The circuit in FIG. **26** may also
17 be built using the lower power dissipation design previously described.

18
19
20 **Item 27: One rack unit power distribution unit using mid-trip circuit breakers with**
21 **lighted status/position indicator and alarm test circuit, for a positive ground DC**
22 **system.**

23
24 *Description:*

25 Shown in FIG. **28**, the 1 rack unit (RU) power distribution unit (PDU) receives up to two
26 independent sources of DC power at the input, and distributes these two input power
27 streams to several outputs. The total number of outputs that may be supported depends on
28 the total current capability of the input power streams, and on the current requirements of
29 the each output. The 1-RU PDU incorporates many of the technologies claimed in Items
30 1 through 26.



1 Depending upon what system in which the PDU is used, either the positive or the
2 negative lines from the input DC power streams will pass through circuit breakers to each
3 output. These circuit breakers may or may not be of the mid-trip variety, and may or may
4 not include auxiliary switches. The auxiliary switch of each circuit breaker could be used
5 either for the remote monitoring of the status of the circuit breakers, or to activate
6 separate circuits for control or alarm purposes.

7

8 Included in the 1-RU PDU are lighted status indicator circuits, as well as circuits for
9 remote monitoring of the PDU status, when one or more of its output circuits are
10 interrupted by circuit breaker(s). Output connectors for the 1-RU PDU may be either
11 individual to each output stream, or combined into one or more modules.

12

13 The positive and negative of each input line is connected to individual bus bars from
14 which sets of cables flow power to the different outputs, passing through the circuit
15 breakers and lighted status indicator circuits.

16

17 Depending on the system configuration, the cables that run the power to the outputs
18 through the circuit breakers are either positive or negative. A second wire of each output
19 (return) that does not run current through the circuit breaker is directly connected to the
20 output. For a positive ground DC system, the negative line goes through the circuit
21 breakers, and all loads are located between the positive side of the power supply and the
22 circuit breakers. In the case of a negative ground DC system the positive line goes
23 through the circuit breakers, and all loads are located between the negative side of the
24 power supply and the circuit breakers.

25

26 FIG. 26 diagrams the lighted status indicator circuit used in this type of the system. Two
27 sets of lighted status indicator/breaker group circuits, and a circuit for the remote
28 monitoring of the PDU, are shown in FIG. 27.

29

30 In this 1-RU PDU, each set of circuits drives the lighted status indicators associated with
31 the circuit breakers in that set. Each set of circuit breakers also receives power from only

one input power stream. The two sets of circuits (each powered by the one of the two separate input power streams) are electrically isolated from each other. A single DPDT (double pole, double throw) momentary test switch **332/347** is used for testing both sets of circuits. One side of the switch is used for one set of circuits and the other side is used for the second set of circuits.

6

Elements of the FIG. 27 Circuit:

| | |
|---|---|
| 320 –Circuit Breaker (A-side) | 336 –Load (B-side) |
| 321 –Load (A-side) | 337 –Diode (B-side) |
| 322 –Diode (A-side) | 338 –Resistor (B-side) |
| 323 –Resistor (A-side) | 339 –Diode (B-side) |
| 324 –Diode (A-side) | 340 –Bi-Color LED (B-side) |
| 325 –Bi-Color LED (A-side) | 341 –Diode (B-side) |
| 326 –Diode (A-side) | 342 –Diodes D1 through D _n (B-side) |
| 327 –Diodes D1 through D _n (A-side) | 343 –Diode (B-side) |
| 328 –Diode (A-side) | 344 –Relay (B-side) |
| 329 –Relay (A-side) | 345 –Resistor (B-side) |
| 330 –Resistor (A-side) | 346 –Diodes D1 through D _n (B-side) |
| 331 –Diodes D1 through D _n (A-side) | 347 –Momentary Test Switch (B-side) |
| 332 –Momentary Test Switch (A-side) | 348 –Auxiliary Switch (B-side) |
| 333 –Auxiliary Switch (A-side) | 349 –Resistor (B-side) |
| 334 –Resistor (A-side) | 350 –PDU Status Output |
| 335 –Circuit Breaker (B-side) | |

24

Elements of FIG. 28:

| | |
|-----------------------------|-----------------------------|
| 351 –PDU, Front View | 352 – PDU, Rear View |
|-----------------------------|-----------------------------|

27

Function:

Under normal operating conditions (circuit breakers are in the CLOSED/ON state), when the input power streams are applied, and there has been no over-current condition in any of the circuit breakers, the relays for the input power stream “A” **329** and for the input

power stream “B” **344** are activated, and contacts of both relays are closed. The contact closure of relay “A” **329**, in series with a similar contact closure for relay “B” **344** (used with input power stream “B”), is used for the remote monitoring of the status of the PDU through a connector **350** on the back of the unit.

Since manually setting any circuit breaker **320/335** to the OFF position does not affect the status circuit for that circuit breaker’s alarm, the relay **329/344** will stay energized whether or not any circuit breaker **320/335** is set to the CLOSED/ON position, or is manually turned OFF.

When an over-current condition occurs in any of the circuit breakers **320/335**, causing it to trip, or whenever the momentary alarm test switch **332/347** is pressed, the +VDC voltage associated with that breaker **320/335** will reach the negative side of the associated relay coil through the OR-ing diodes. This will cause the relay coils to have approximately the same positive voltage at both ends. Thus the relay **329/344** will no longer be energized, and the relay contact used for the remote monitoring of the PDU will open, indicating either an over-current (TRIPPED) condition, or that an alarm test taking place.

Since the two contacts of the relays “A” and “B” **329/344** are connected to each other in series, an opening of either relay contact will cause an open loop condition in the status circuit, connected to the status connector **350** on the back of the PDU. The absence of either input power “A” or “B” will cause the relay **329/344** for that particular power side not to energize, opening loop of the status output **350**, and indicating an alarm condition. The circuit in FIG. **27** may also be built using the lower power dissipation designs previously described.

FIG. **28** shows the front panel **351** and back panel **352** of a six-output, one-RU PDU. The front panel displays the status LED associated with each of the lighted status indicator circuits, while the rear panel shows the final status output connector, as well as the input and output connectors.



Item 28: Compact circuit breaker incorporating a mid-trip switch, a lighted status indicator for the ON/OFF/TRIPPED positions, auxiliary “normally open”/“normally closed” contact points for remote monitoring of the circuit breaker system, and an alarm circuit momentary test switch, for AC or a positive or negative ground DC system.

FIG. 29 shows a compact circuit breaker that incorporates a mid-trip switch, a lighted status indicator, auxiliary “normally open”/“normally closed” contact points (358 and 359) for remote monitoring of the breaker, and an alarm circuit momentary test switch 355. With appropriate changes to the internal circuitry (as shown in FIGS. 30 through 34), this design can support AC power supplies, and/or positive or negative ground DC power supplies. Lower power dissipation versions of this circuit could also be used in compact circuit breakers. The compact circuit breaker shown in FIG. 29 could also be implemented with or without the alarm circuit and momentary test switch.

Elements of FIG. 29:

| | |
|---|---|
| 353 –Circuit Breaker Handle | 358 –"Normally Open" Status Contact |
| 354 –Bi-Color LED | 359 –"Normally Closed" Status Contact |
| 355 –Alarm Test Switch | 360 –"Center" Status Contact |
| 356 –Power Connection to Load (return) | 361 –Power Connection to Line (supply) |
| 357 –Power Connection to +VDC Supply | |

Description:

FIG. 30 diagrams the basic compact circuit breaker circuit (for a positive ground DC system). This circuit includes: a main contact 362 that carries the current to the load, a Diode 364 with its cathode connected to the load side of the main contact 362, a Resistor 370, where one side is connected to the line side (in this case negative) of the main contact 362, and the other side to a Bi-color LED 366. It also incorporates a DPDT (dual pole, dual throw) auxiliary switch 367 that activates only when the main contact of the circuit breaker 362 has been tripped by over-current flow through the main contact, and a miniature pushbutton SPDT (single pole, double throw) momentary test switch 368.



1 *Elements of the FIG. 30 Circuit:*

2 **362**–Circuit Breaker Main Contact

3 **363**–Load

4 **364**–Diode

5 **365**–Resistor

6 **366**–Bi-Color LED

7

8 *Elements of the FIG. 31 Circuit:*

9 **371**–Circuit Breaker Main Contact

10 **372**–Load

11 **373**–Diode

12 **374**–Resistor

13 **375**–Bi-Color LED

14

15 *Function:*

16 The FIG. 30 circuit is designed for use only in a circuit breaker with mid-trip capability.
17 In such a breaker, the main contact of the circuit breaker **362** opens in trip mode, only if
18 over-limit current is passing through the main contact.

19

20 Under normal operating condition, when the main contact **362** is closed (breaker is in the
21 CLOSED/ON state), current will flow from the +VDC input pin, through the “normally
22 closed” position of the momentary test switch **368**, and through the center position of the
23 first section of the DPDT auxiliary switch **367** (through its “normally closed” contact).
24 Current flow will continue through the bi-color LED **366**, the resistor **365**, the diode **364**,
25 finally reaching the main contact **362** of the negative side of the power supply. This
26 direction of current flow passes through the forward bias green chip of the LED **366**
27 causing it to glow GREEN.

28

29 When an over-current condition causes the main contact **362** to trip “open” (breaker is in
30 the TRIPPED state), the DPDT auxiliary switch **367** also changes its position. In the
31 TRIPPED state, current will flow through the first section of the auxiliary switch **367** (via

the “normally open” path), the LED **366** (but in the opposite direction than in the CLOSED/ON condition), the resistor **370**, and on to the negative point of the power supply. As a result, the LED **366** will turn RED, indicating a tripped condition. In this TRIPPED condition, no current will flow through the diode **364** because the main contact of the breaker is open. A second section of the DPDT auxiliary switch **367** will change the state used for remote monitoring of circuit breaker status.

When the circuit breaker is in normal operating condition (CLOSED/ON), or has been manually opened (OFF), pressing the momentary test switch **367** will cause the LED **366** to turn RED. Current flowing through the “normally open” contact of the momentary test switch **368**, to the “normally open” contact of the auxiliary switch **367**, and on to the negative side of the power supply (passing through the LED **366** and the resistor **370**), causes LED **366** to glow RED.

Since this current flow is the same whether the main contact of the circuit breaker **362** is closed or manually opened, depressing the momentary test switch **368** will test the RED alarm condition of the LED **366** for either case. In both cases, it will simulate an open line of current flow through the “normally closed” contact of the DPDT auxiliary switch **367**.

The values and power rating of the resistors selected for the circuit will depend on the desired intensity for the LED **366** (for both RED and GREEN states), and on the power levels the circuit is designed to tolerate.

While the FIG. **30** circuit has been configured to support a positive ground DC system, a similar approach could easily be used for a negative ground DC system. This circuit would require only minor modifications (including reversal of the direction of the diode **364** and LED **366**) to support a circuit breaker located between the positive side of power supply and load **363** (as in the FIG. **13** circuit). The circuit in FIG. **30** may also be built using the lower power dissipation circuits previously described.



While the FIG. 32 circuit has been configured to support a positive ground DC system, as before, a similar approach could easily be used for a negative ground DC system. This circuit would require only minor modifications (including reversal of the direction of the current-limiting diodes 384 and 389 and bi-color LED 385) to support a circuit breaker located between the positive side of power supply and load 381 (as in the FIG. 13 circuit). The circuit in FIG. 32 may also be built using the lower power dissipation designs previously described.

Item 30: Circuit diagram for the compact circuit breaker incorporating a mid-trip switch, with lighted status indicator for ON/OFF/TRIPPED positions, auxiliary “normally open”/“normally closed” contact points for remote monitoring of the circuit breaker system, and an alarm circuit momentary test switch, for AC systems or positive ground DC systems.

Description:

The circuit shown in FIG. 33 is identical to the FIG. 30 circuit, save for the addition of a diode 400 between the resistor 399 and the VAC return.

Elements of the FIG. 33 Circuit:

| | |
|--|--|
| 391 –Circuit Breaker Main Contact | 396 –Auxiliary Switch |
| 392 –Load | 397 –Alarm Test Momentary Switch |
| 393 –Diode | 398 –Connector on back of Circuit Breaker |
| 394 –Resistor | 399 –Resistor |
| 395 –Bi-Color LED | 400 –Diode |

Function:

Adding the extra diode 400 allows the circuit to be used with both AC and positive ground DC power supplies. As before, the FIG. 33 circuit could easily be reconfigured to support a negative ground DC system with minor modifications (including reversal of the

1 Like circuits in FIG. 30 through FIG. 33, the FIG. 34 circuit could easily be reconfigured
2 to support a negative ground DC system with minor modifications (including reversal of
3 the direction of the diodes 403 and 412, the current-limiting diodes 405 and 410, and bi-
4 color LED 406). The circuit in FIG. 33 may also be built using the lower power
5 dissipation designs previously described.

6

7

8 **Item 32—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a**
9 **main contact and an auxiliary switch SPDT for tripped status indication, for a**
10 **positive ground DC system.**

11

12 *Description:*

13 In the circuit diagrammed in FIG. 35, the circuit breaker includes two switches (413 and
14 414). The main contact 413 can be turned ON or OFF manually, and will be turned OFF
15 automatically when the current running through the circuit breaker main contact 413
16 exceeds a preset value. The auxiliary switch 414 will be in the ON position except when
17 the main contact 413 has been activated automatically by a current overload, and has
18 tripped to the OFF position. In such a case, the auxiliary switch 414 will also be moved to
19 the OFF position.

20

21 *Elements of the FIG. 35 Circuit:*

| | | |
|-------------------------|------------------|----------|
| 22 413—Main Contact | 416—Resistor | 419—Load |
| 23 414—Auxiliary Switch | 417—Bi-Color LED | |
| 24 415—Resistor | 418—Diode | |

25

26 *Function:*

27 When the circuit breaker has been manually set to the OFF position, the auxiliary switch
28 414 stays in the ON position, and the supply voltage (-VDC) is completely disconnected
29 from the circuit and no current flows through the bi-color LED 417 (the bi-color LED
30 414 is in the OFF state).

31



1 When the circuit breaker is manually set to the ON position, the auxiliary switch **414**
2 remains in the ON position (and is disconnected from resistor **415** and the bi-color LED
3 **417**), and the supply (-VDC) is connected to the diode **418** and the load **419**. In this
4 configuration, a current flows from the positive ground, through the resistor **415**, the
5 GREEN LED of the bi-color LED **417**, the diode **418**, the main contact **413**, and on to the
6 supply (-VDC). Therefore when the current running through the circuit breaker main
7 contact **418** is within the preset limit, the auxiliary switch **414** remains in the ON position,
8 and the bi-color LED **417** glows GREEN. A second current flows through the circuit
9 running from the positive ground, through the resistor **416**, the diode **418**, the main
10 contact **413**, and on to the supply (-VDC).

11

12 When the current flowing through the main contact **413** exceeds the preset value, the
13 circuit breaker will be activated and both the main contact **413** and the auxiliary switch
14 **414** will shift to their OFF positions. In this case, the main contact **413** will disconnect the
15 load and the diode **418** from the supply voltage (-VDC). The auxiliary switch **414** (now
16 also tripped to its OFF position) will cause the supply voltage (-VDC) to be connected to
17 the resistor **415** and to the bi-color LED through the main contact **413** and the auxiliary
18 switch **414**. In this case, a current will flow from the positive ground, through the resistor
19 **416**, the RED LED of the bi-color LED **417**, the auxiliary switch **414**, the main contact
20 **413**, and on to the supply (-VDC). A second flow of current will run from the positive
21 ground, through the resistor **415**, the main contact **413** and the auxiliary switch **414**, to
22 the supply (-VDC). The amounts of both currents are limited by resistor values.

23 Therefore when an overcurrent condition causes the circuit breaker to trip, both the main
24 contact **413** and the auxiliary switch **414** will be activated. Only under this condition will
25 the bi-color LED **417** glow RED.

26

27 The resistors **416** and **415** may be replaced with current-limiting diodes. Several current-
28 limiting diodes may be used in series in order to use the FIG. 35 circuit with higher
29 supply voltages.

30

31

FIG. 35

Item 33—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a main contact and an auxiliary switch SPDT for tripped status indication for a negative ground DC system.

Description:

The FIG. 36 circuit is the same as the circuit shown in FIG. 35, except that the direction of the diode 425 and the bi-color LED 424 have been reversed, in order to allow the circuit to work in a negative ground DC system.

Elements of the FIG. 36 Circuit:

| | | |
|----------------------|------------------|----------|
| 420—Main Contact | 423—Resistor | 426—Load |
| 421—Auxiliary Switch | 424—Bi-Color LED | |
| 422—Resistor | 425—Diode | |

Function:

When the circuit breaker (main contact 420 and auxiliary switch 421) is manually turned OFF the load 426, and the diode 425, are disconnected from the supply (+VDC) causing the bi-color LED 424 to remain in its OFF state.

When the circuit breaker is turned to the ON position—and the current through the circuit breaker is within the preset limits—the main contact 420 remains in the ON position and is disconnected from the resistor 422 and the bi-color LED 424. In this state of the circuit, a current will flow through the main contact 420, the diode 425, the GREEN LED of the bi-color LED 424, the resistor 422, and on to the ground. A second current exists, flowing through the main contact 420, the diode 425, the resistor 423, and on to the ground.

When the circuit breaker is activated due to an overcurrent condition, the main contact 420 and the auxiliary switch 421 will both shift to their OFF positions. In this state, the only current flowing through the circuit will be: (a) from the +VDC supply, through the main contact 420, the auxiliary switch 421, the RED side of the bi-color LED 424, resistor



1 423, and on to the ground; and (b) from the +VDC supply through the main contact 420,
2 the auxiliary switch 421, the resistor 422, and on to the ground. Thus only the tripped
3 condition of the breaker will cause the RED side of the bi-color LED 424 to be activated.

4
5
6 **Item 34—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a**
7 **main contact and an auxiliary switch SPDT for tripped status indication for a**
8 **positive ground DC or an AC system.**

9
10 *Description:*

11 The circuit shown in FIG. 37 is identical to that shown in FIG. 35, except for the
12 placement of a diode 429, between the resistor 430 and the OFF contact position of the
13 auxiliary switch 428.

14
15 *Elements of the FIG. 37 Circuit:*

| | | |
|-------------------------|------------------|-----------|
| 16 427—Main Contact | 430—Resistor | 433—Diode |
| 17 428—Auxiliary Switch | 431—Resistor | 434—Load |
| 18 429—Diode | 432—Bi-Color LED | |

19
20 *Function:*

21 The addition of the diode 429 will cause current to flow only in a half-cycle through the
22 circuit. Half-cycle current flow only occurs when the ground polarity is positive with
23 respect to the –VDC supply. The circuit is only active during this half-cycle time for both
24 RED and GREEN displays of the bi-color LED 432.

25
26 Otherwise, the function of this circuit is identical to the circuit described under FIG. 35.

27
28
29 **Item 35—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a**
30 **main contact and an auxiliary switch SPDT for tripped status indication for a**
31 **negative ground DC or an AC system.**

| | | | |
|---|------------------------------|--------------------------|-------------------|
| 2 | 443 –Main Contact | 446 –Resistor | 449 –Diode |
| 3 | 444 –Auxiliary Switch | 447 –Resistor | 450 –Load |
| 4 | 445 –Diode | 448 –Bi-Color LED | |

6 *Function:*

7 When the circuit breaker is manually turned off, the load and the Diode **449** are
8 disconnected from the +VDC supply (the auxiliary switch **444** being in the OFF state), the
9 bi-color LED **448** will be in the OFF state, as well.

When the circuit breaker is turned to the ON position—and the current through the circuit breaker is within the preset limits—the main contact **443** will remain in the on position and be disconnected from the diode **445**, the resistor **446**, and the bi-color LED **448**. In this state, a current will flow through the main contact **443**, the diode **449**, the Green LED of the bi-color LED **448**, the resistor **446**, and on to the ground. A second current will also exist, flowing through the circuit breaker main contact **443**, the diode **449**, the resistor **447**, and on the ground.

When the circuit breaker is activated due to an overcurrent condition, the main contact 443 will shift to the OFF position, and the auxiliary switch 444 will shift to the ON (TRIPPED) position. In this state, the only currents flowing through the circuit will be:

(a) From the +VDC supply, through the main contact's **443** center contact, the auxiliary switch **444** contact, the diode **445**, the RED side of the bi-color LED **448**, the resistor **447**, and on to the ground, and

(b) From the +VDC supply, through the main contact's **443** center contact, the auxiliary switch **444** contact, the diode **445**, the resistor **446**, and on to the ground.

29 Thus only the TRIPPED condition of the breaker will cause the RED side of the bi-color
30 LED 448 to be activated.

Item 37—Lighted Status Indicator for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch SPST for tripped status indication for a positive ground DC or an AC system.

Description:

The circuit diagrammed in FIG. 40 is similar to the circuit shown in FIG. 37, with the following exceptions:

- (1) The main contact **451** is a SPST (single pole, single throw) switch, normally placed in the OFF position (the circuit is in the OFF position), and can be turned ON or OFF manually and turned OFF automatically (TRIPPED mode).
- (2) The auxiliary switch **452** is a SPST (single pole, single throw) switch, normally placed in the OFF position which will only shift to the ON position when the main circuit breaker contact **451** is tripped.
- (3) The center points of the main contact **451** and the auxiliary switch **452** are connected to each other and to the -VDC.

Elements of the FIG. 40 Circuit:

| | | |
|------------------------------|--------------------------|-----------------------|
| 451 —Main Contact | 455 —Resistor | 459 —Point "B" |
| 452 —Auxiliary Switch | 456 —Bi-Color LED | 460 —Point "D" |
| 453 —Diode | 457 —Diode | |
| 454 —Resistor | 458 —Load | |

Function:

When the main contact **451** is in the OFF position, the auxiliary switch **452** is also in the OFF position, and -VDC is disconnected from the diode and the load. But when the main contact **451** is set in the ON position, the -VDC supply is connected to the Load **458** and Diode **457**, and the auxiliary switch **452** remains in the OFF position and disconnected from the diode **453**, the bi-color LED **456**, and the resistor **454**.

Besides the main current flowing through the load, a current flow will run from the positive (+) ground through the resistor **454**, through the GREEN side of the bi-color LED **456**, the diode **457**, the main contact **451**, and on to the -VDC. A second current flow will run from the positive (+) ground, through the resistor **455**, the diode **457**, the main contact **451**, and on to the -VDC. In this state, the GREEN LED of the Bi-Color LED **456** will indicate that the circuit is ON and normally operational.

When an overcurrent load condition causes the main circuit breaker contact **451** to trip, the main contact **451** will open up the current flow to the load and the diode **457**. At the same time, the auxiliary switch **452** will flip to its ON state and connect -VDC to the diode **453**, the bi-color LED **456**, and the resistor **454**. In this condition of the circuit, a current flows from the positive (+) ground through the resistor **455**, the RED side of the bi-color LED **456**, the diode **453**, the auxiliary switch **452**, the center of breaker main contact **451**, and on to the -VDC. A second current path exists from the positive (+) ground, through the resistor **454**, the diode **453**, the auxiliary switch **452**, the center of the main contact **451**, and on to the -VDC supply. In this state, the RED side of the bi-color LED **456** will be ON, indicating that the breaker has tripped.

Resistors **455** and **454** may be replaced with current-limiting diodes. Also, several current-limiting diodes may be used in series to modify the FIG. **40** circuit for use with higher supply voltages. A circuit identical to the FIG. **40** circuit may be used for a negative ground DC system if the direction of the diodes (**457** and **453**) and the bi-color LED **456** are reversed.

Item 38—Lighted Status Indicator for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch SPST (or SPDT) for tripped status indication with alarm test push button switch, for a positive ground DC or an AC system.

1 *Description:*

2 The circuit diagrammed in FIG. 41 is identical to that shown in FIG. 40, except that a
3 diode has been added between Points B 472 and D 474, and a push button alarm test
4 switch 464 (momentary, normally open) has been added on a line between the –VDC
5 supply and the SPST auxiliary switch 462 (the line passing through Point C 473).

7 *Elements of the FIG. 41 Circuit:*

| | |
|---|--------------------------|
| 8 461 –Main Contact | 468 –Bi-Color LED |
| 9 462 –Auxiliary Switch (SPST) | 469 –Diode |
| 10 463 –Auxiliary Switch (SPDT option) | 470 –Diode |
| 11 464 –Push-Button Alarm Test Switch | 471 –Load |
| 12 465 –Diode | 472 –Point "B" |
| 13 466 –Resistor | 473 –Point "C" |
| 14 467 –Resistor | 474 –Point "D" |

16 *Function:*

17 When the push button test switch 464 is not pressed, this circuit functions identically to
18 the FIG. 40 circuit. However, when the push button test switch 464 is pressed, it bypasses
19 the main contact 461 and the auxiliary switch 462, causing the supply voltage to be
20 applied to the tripped contact of the auxiliary switch 462, thus simulating a tripped
21 condition for the auxiliary switch 462, regardless of the position of the main contact 461.

23 This circuit allows two possible positions of the main contact 461—OFF and ON. Circuit
24 function for both positions is detailed below.

26 If the main contact 461 is in the OFF position then a current flow will exist from the
27 positive ground through the resistor 466, the diode 465, the push button test switch 464,
28 and on to the –VDC supply. A second current flow will run from the positive ground
29 through the resistor 467, the RED LED of the bi-color LED 468, the diode 465, the push
30 button test switch 464, and on to the –VDC supply. This current flow will cause the RED

side of the bi-color LED **468** to glow, indicating that the alarm circuit is working properly.

If the main contact **461** is in the ON position while the –VDC supply is powering the load, the two current flows described above exist—along with a third current path that flows from the positive ground, through the resistor **467**, the diodes **469** and **470**, the main contact **461**, and on to the –VDC supply.

The addition of the diode **470** (or a resistor in its place) will cause the voltage at point D **474** to be positive enough with respect to point C **473**, to cause the RED side of the bi-color LED **468** to turn ON and the GREEN side of the bi-color LED **468** to turn OFF (points B **472** and C **473** are at the –VDC potential). Thus the RED side of the bi-color LED **468** will indicate the proper functionality of the alarm circuitry without having any effect on the supply voltage to the Load **471**.

Notes: Diode **470** may be replaced by a Zener diode or a resistor; resistors **467** and **466** may be replaced with current-limiting diodes; and Diode **465** is used for AC applications.

The circuit in FIG. **41** will also function identically with a SPDT auxiliary switch **463** substituted for the SPST auxiliary switch **462** shown in the main circuit diagram (see also Item 39 below).

Item 39—Lighted Status Indicator for a mid-trip circuit breaker using a SPST as a main contact and an auxiliary switch (SPDT) for tripped status indication with alarm test push button switch, for a positive ground DC or an AC system.

Description:

This circuit in FIG. **42** details the SPDT (single pole, double throw) for the auxiliary switch **477** version of FIG. **41** designed for a positive ground DC (or AC) system. This

1 version of the circuit has the auxiliary switch **477** placed differently in the circuit and the
 2 diode **470** (of FIG. **41**) is replaced with a resistor **484**.

3

4 *Elements of the FIG. 42 Circuit:*

| | |
|---------------------------------------|---|
| 5 475 —Point "A" | 482 —Bi-Color LED |
| 6 476 —Main Contact (SPST) | 483 —Resistor |
| 7 477 —Auxiliary Switch (SPDT) | 484 —Resistor |
| 8 478 —Point "C" | 485 —Diode |
| 9 479 —Diode | 486 —Point "B" |
| 10 480 —Resistor | 487 —Load |
| 11 481 —Point "D" | 488 —Push-Button Alarm Test Switch |

12

13 *Function:*

14 This circuit works like FIG. **41** circuit, except that the FIG. **42** configuration (and not the
 15 configuration of FIG. **41**) is used when multiple circuit breakers are connected to the
 16 same push-button alarm test switch **488** (momentary, normally open).

17

18 In such a case, when the alarm test switch **488** is pressed, all alarm circuits are tested at
 19 the same time within the same system (positive or negative ground). Also in this version
 20 of the circuit, when a circuit breaker is tripped, the circuit associated with that circuit
 21 breaker will be disconnected from the test switch **488**.

22

23

24 **Item 40—Lighted Status Indicator for a mid-trip circuit breaker using a SPDT as a**
 25 **main contact and an auxiliary switch (SPDT) for tripped status indication with**
 26 **alarm test push button switch, for a negative ground DC (or an AC) system.**

27

28 *Description:*

29 This circuit in FIG. **43** is the negative ground DC version of the circuit in FIG. **42**. It is
 30 identical to the FIG. **42** circuit except that the directions of the diodes **499** and **493** and
 31 the bi-color LED **496** have been reversed.

1 *Elements of the FIG. 43 Circuit:*

2 **489**—Point "A"

496—Bi-Color LED

3 **490**—Main Contact (SPST)

497—Resistor

4 **491**—Auxiliary Switch (SPDT)

498—Resistor

5 **492**—Point "C"

499—Diode

6 **493**—Diode

500—Point "B"

7 **494**—Resistor

501—Load

8 **495**—Point "D"

502—Push-Button Alarm Test Switch

9

10 *Function:*

11 The FIG. 43 circuit functions identically to the circuit diagrammed in FIG. 42, except that
12 the direction of the diodes **499** and **493**, bi-color LED **496**, and current flow are reversed.

13

14

15 **Item 41—Lighted Status indicator for a fuse with alarm circuit and alarm test**
16 **switch, for a positive ground DC (or AC) system.**

17

18 *Description:*

19 The FIG. 44 circuit is functionally identical to the FIG. 41 circuit except that a fuse **503**
20 has replaced the main contact **461** and the auxiliary switch **462** (of FIG. 41).

21

22 *Elements of the FIG. 44 Circuit:*

23 **503**—Fuse with Alarm Contact

509—Resistor

24 **504**—Push-Button Alarm Test Switch

510—Diode

25 **505**—Diode

511—Resistor

26 **506**—Resistor

512—Point "B"

27 **507**—Point "A"

513—Load

28 **508**—Bi-Color LED

29

30

31

Function:

The circuit in FIG. 44 functions identically to the circuit shown in FIG. 41. Removal of the fuse 503 corresponds to manually turning off the power to the Load 513. In this case, the –VDC is completely disconnected from Points A 507 and B 512. When excessive current at the Load 513 blows the fuse 503, Point B 512 will be disconnected from the –VDC supply, and the diode 505 will be connected to the –VDC supply through Point A 507 of the fuse 503.

Reversing the directions of the diodes 510 and 505 and the bi-color LED 508 creates a version of this circuit for use with a negative ground DC supply.

Item 42—Compact Module (L-Module) for Display of Individual Breaker Status.

Description:

The “L-Module” 515 (detailed in FIG. 45) is a compact, breaker-mounted module that provides a front panel visual display of the exact status of a circuit breaker equipped with an auxiliary status switch (where the status switch is only activated in the TRIPPED state of the breaker). Breaker status is indicated via an LED status indicator 519 located next to the breaker. This LED status indicator 519 and associated status circuitry are encased inside of a compact module—the L-Module 515—attached to the connector lugs on the back of the circuit breaker 514.

Elements of FIG. 45:

| | | |
|----------------------|--------------------------|----------------------------------|
| 514 —Breaker | 516 —Load Contact | 518 —Status/Test Port |
| 515 —L-Module | 517 —Line Contact | 519 —LED Status Indicator |

1 *Elements of FIG. 46:*

2 **520**—Line and Load Contacts

3 **521**—Daisy-Chain Cable

4 **522**—Status/Test Port

5 **523**—L-Module 1

6 **524**—L-Module 2

7 **525**—L-Module n

8 **526**—Breaker 1

9

10 *Function:*

11 The FIG. 40 circuit diagram (shown in Item 37) shows the design of the basic L-Module
12 circuit. FIG. 41 (shown under Item 38) diagrams the L-Module **515** with an added alarm
13 test function. Note that just as in Item 38, resistors **467** and **466** (of FIG. 41) may be
14 replaced with current-limiting diodes. Similarly, diode **465** (of FIG. 41) may be added for
15 use with for AC applications, and a Zener diode or a resistor may replace diode **470** (of
16 FIG. 41).

17

18 As shown in FIG. 46, Multiple L-Modules (**523**, **524**, and **525**) may be connected in
19 series, allowing a panel of breakers with L-Modules to all be tested using one common
20 test switch **532** (in FIG. 46) or **488** (in FIG. 42) using the FIG. 42 circuit. That common
21 test switch, along with an alarm status contact provision **530**, is placed in a separate
22 module—the Alarm/Status Module **529** (in FIG. 46) (see Items 43 and 44). Test lines and
23 a ground path **521** for each L-Module are daisy-chained and terminated in the
24 Alarm/Status Module **529** (in FIG. 46). (Alarm/Status Module is hereafter abbreviated as
25 A/S-Module.)

26

27

28

29

30

31

527—Breaker 2

528—Breaker n

529—Alarm/Status Module (A/S-Module)

530—A/S-Module Alarm Summary Out

531—A/S-Module Ground Contact

532—Alarm Test Switch

Item 43—Alarm/Status Module (Used in a Single Power System).

Description:

An A/S-Module for a single power system (shown in FIG. 47) consists of a relay circuit **560** and a SPST (single pole, single throw), momentary, normally open, push-button switch **559** (the Alarm Test Switch), as well as a resistor **561**, a capacitor **562**, and a diode **563**.

The alarm test switch extends from the front of the A/S-Module. Pressing it tests all alarm circuits within the L-Modules, as well as the A/S-Module's dry contact alarm summary output. Pressing the alarm test switch will also turn all of the L-Module bi-color LEDs RED—regardless of breaker positions. Such a test does not impact normal breaker function, or in any way affect the current moving through the breaker.

A/S-Module inputs come from daisy-chained L-Module status lines that terminate at the A/S-Module (as shown in FIGS. 46 and 47). The A/S-Module outputs alarm summary information for all connected breakers, from the contact points **564** of a SPDT relay **560** inside the A/S-Module, via a three-position connector.

An A/S-Module can be configured as to allow the alarm test switch **559** to be panel mounted, while the A/S-Module itself is located remotely. With this design only a minimum of panel space—just enough to mount the switch—is required.

FIG. 47 diagrams an A/S-Module together with the L-Modules it receives inputs from.

Elements of the FIG. 47 circuit:

| | |
|---------------------------------------|-----------------------------|
| 533 —Point "A-1" | 549 —Isolation Diode |
| 534 —Main Contact 1 (SPST) | 550 —Diode |
| 535 —Auxillary Switch 1 (SPDT) | 551 —Resistor |
| 536 —Isolation Diode | 552 —Point "D-n" |
| 537 —Diode | 553 —Bi-Color LED |
| 538 —Resistor | 554 —Resistor |

| | | |
|----|---|-------------------------------|
| 1 | 539 –Point "D-1" | 555 –Resistor |
| 2 | 540 –Bi-Color LED | 556 –Diode |
| 3 | 541 –Resistor | 557 –Point "B-n" |
| 4 | 542 –Resistor | 558 –Load n |
| 5 | 543 –Diode | 559 –Alarm Test Switch |
| 6 | 544 –Point "B-1" | 560 –Relay |
| 7 | 545 –Load 1 | 561 –Resistor |
| 8 | 546 –Point "A-n" | 562 –Capacitor |
| 9 | 547 –Main Contact n (SPST) | 563 –Diode |
| 10 | 548 –Auxillary Switch n (SPDT) | 564 –Status Out |

Function:

Input lines to the A/S module are:

- (1) A supply voltage and return (ground) line,
- (2) A line that connects (daisy-chained) the isolation diodes (running from **536** to **549**), of all the L-Modules being monitored, and
- (3) A line that connects (daisy-chained) all the normally closed contact positions of the monitored L-Module's auxiliary switches 1 through n (**535** and **548**).

During the normal operation of the monitored breakers, there is no current flow through any of the L-Modules' isolation diodes (**536** and **549**), the A/S-Module relay **560** is energized through diode **563** and resistor **561**, and outputs from the A/S-Module relay contacts **564** indicate proper functioning of all breakers.

When an overload condition causes one or more of the L-Modules to report a TRIPPED condition in the breakers they monitor, a current will flow from the positive ground, through diode **563** and resistor **561**, the isolation diode(s) (**536** and/or **549**) of the L-Module(s) connected to the tripped auxiliary switch (**535** and/or **548**), to the breaker(s) main contact (**534** and/or **547**), and on to the –VDC supply. As a result, the voltage differential across the A/S-Module relay **560** drops to about 0.7 Volts (diode drop), de-



energizing that relay **560**, causing the relay status contacts **564** to report an alarm condition. This alarm contact condition also exists whenever system power is interrupted. Note that the capacitor **562** is used for an AC-powered system.

The push-button momentary switch **559** (alarm test switch) of the A/S-Module is used to test proper functioning of all L-Module LED status indicator circuits, as well as the relay circuit within the A/S-Module itself. Pressing the alarm test switch **559** will cause the connection of the –VDC supply voltage to all L-Modules via the normally closed contact of their auxiliary switches (**535** and **548**). This connection triggers current flows from the positive ground, through the RED sides of the L-Modules' bi-color LEDs (**540** or **553**), through their auxiliary switches (**535** and **548**), the A/S-Module's push-button alarm test switch **559**, and on to the –VDC supply at the A/S-Module.

Pressing the alarm test switch **559** also connects the isolation diodes (**536** and D6 **549**) within all L-Modules to the –VDC supply, causing the relay **560** to de-energize, thus simulating a TRIPPED condition within one or more of the monitored L-Modules.

Item 44—Alarm/Status Module (Used in a Dual Power System).

Description:

This version of the A/S-Module is similar to the A/S-Module used for single power systems, except that the momentary, alarm test switch **567** is a DPST (double pole, single throw) switch, and that a second relay **566** is added for the second power system. (FIG. **48** illustrates the circuit used for the Dual Power System A/S-Module.)

The relay contacts are daisy-chained together (via the Normally Open contacts—see FIG. **48**) to create one single status output for the entire system. Inputs to the A/S-Module are via two groups of lines—one group for each power system. The A/S-Module is designed so as to keep the two independent power systems completely isolated from each other. Since the normally open contacts of the two relays (**565** and **566**) are daisy-chained



1 together, the A/S-Module will report an alarm status when an over current condition
2 occurs in any breaker of either of the two independent power systems. The A/S-Module
3 will also report an alarm if either—or both—of the power systems A and B is absent.
4

5 Adding the capacitors **569** and C2 **572** (drawn in dotted lines), creates a version of the
6 circuit for use in an AC power system.
7

8 *Elements of the FIG. 48 circuit:*

| | | |
|-----------------------------------|-----------------------|-----------------------|
| 9 565 —Relay 1 (A-Side) | 568 —Diode | 571 —Diode |
| 10 566 —Relay 2 (B-Side) | 569 —Capacitor | 572 —Capacitor |
| 11 567 —Test Switch (DPST) | 570 —Resistor | 573 —Resistor |

12
13 *Function:*

14 This version of the A/S-Module is diagrammed in FIG. 48. It functions in the same way
15 as the Single Power System A/S-Module (FIG. 47), except that the activation of the alarm
16 test switch **567** will test the alarm circuits associated with the breakers in both power
17 systems. The Dual Power System A/S-Module also provides a single alarm status output
18 for the entire system.
19

20 Independent alarm status for each power system may also be provided using relays with
21 DPDT (double pole, double throw) contacts. In this case, the second contact of each relay
22 reports the status of the specific system monitored by that relay.
23

24 25 **Item 45—Direct Status Output L-Module.**

26
27 *Description:*

28 The Direct Status Output L-Module (FIG. 49) is an L-Module which includes part (or all)
29 of the A/S-Module circuitry. It supports independent monitoring of individual circuit
30 breakers. This version of the L-Module incorporates alarm status contacts (**578**, **579**, and
31 **580** on FIG. 49; **583** on FIG. 50) which output at the back of the L-Module. The Direct



1 Status Output L-Module may also include an alarm test switch. This module is designed
2 for use in a system where the status on a specific circuit breaker needs to be
3 independently monitored and reported.

4

5 *Elements of FIG. 49:*

| | |
|--|-----------------------------------|
| 6 574 —Breaker | 579 —Normally Open Contact |
| 7 575 —L-Module | 580 —Center Contact |
| 8 576 —Load Contact | 581 —Line Contact |
| 9 577 —Ground Contact | 582 —LED Status Indicator |
| 10 578 —Normally Closed Contact | |

11

12 *Elements of the FIG. 50 circuit:*

| | | |
|---------------------------|-------------------------------|----------------------|
| 13 583 —Alarm Port | 589 —Auxillary Switch | 595 —Resistor |
| 14 584 —Relay | 590 —Alarm Test Switch | 596 —Resistor |
| 15 585 —Resistor | 591 —Main Contact | 597 —Diode |
| 16 586 —Capacitor | 592 —Diode | 598 —Load |
| 17 587 —Diode | 593 —Resistor | |
| 18 588 —Diode | 594 —Bi-Color LED | |

19

20 *Function:*

21 The Direct Status L-Module circuit (FIG. 50) works in an identical manner to an L-
22 Module and an A/S-Module connected together as one system. Both the L-Module and
23 A/S-Module—and a circuit combining both (FIG. 47)—have previously been described
24 (Items 42 & 43) in detail.

25

26

27

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Item 46—L-module for circuit breakers with no auxiliary switch or circuit breakers with no mid-trip capability.

Description:

The circuit for this version of the L-Module (shown in FIG. 51) is similar to the circuit for the basic L-Module (diagrammed in FIG. 40), with a few significant differences. These include a relay contact **602** that is used in the place of the auxiliary switch of a mid-trip breaker, as well as latch **601** and current-sensing circuits **600** that energize that relay circuit **602**.

Elements of the FIG. 49 circuit:

| | |
|--|--------------------------|
| 599 —Circuit Breaker Main Contact | 605 —Resistor |
| 600 —Current Sense with Delay | 606 —Bi-Color LED |
| 601 —Latch with Power-Up Reset | 607 —Resistor |
| 602 —DPDT Relay | 608 —Resistor |
| 603 —Status Out | 610 —Load |
| 604 —Isolation Diode | 611 —Diode |

Function:

Under normal conditions when the circuit breaker main contact **599** is on, the DPDT (double pole, double throw) relay **602** is not powered, and its normally closed contact (connected to the A/S-Module) does not carry any power. In this state (as has been explained previously), the GREEN side of the Bi-Color LED **606** will turn ON.

When an excessive load current flow occurs, the current-sensing circuit **600** will trigger the latch circuit **601**, applying power to the relay **602**, and activating the relay contacts. The excessive current detection time of the current-sensing circuit is selected so as to be much shorter than the activation time of the circuit breakers being monitored.

When the circuit breaker main contact **599** is tripped, the RED side of the Bi-Color LED **606** will glow. A few milliseconds delay time incorporated in the current-sensing circuit

1 **600** eliminates any chance of circuit activation in case of high initial in-rush current.
 2 When the cause of circuit breaker **599** activation is removed from the load side, the
 3 circuit breaker's **599** manual turn on causes the latch circuit **601** to reset, the relay **602** to
 4 de-energize, and the normal operation of the system to resume.

5
 6 The isolation diode **604** line of the module allows it to be used in daisy chain
 7 configurations (as in the systems shown in FIGS. **47** and **48**). Using a DPDT relay also
 8 provides extra contacts that can be used as status contact out **603**, via the connectors on
 9 the back of the L-Module.

10
 11 As an option, this version of the L-Module also may include a SPST (single pole, single
 12 throw) momentary push button test switch.

13
 14 The circuit contained in this version of the L-Module (FIG. **51**) may also be used to
 15 monitor the status of a switch or a fuse.